Fermi National Accelerator Laboratory

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CDF
Recent Results and Future Prospects

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March 1992

Presented at the *2nd Topical Conference on Physics of e+e- Collisions*, KEK, Tsukuba, Japan, November 28, 1991.

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CDF, Recent Results and Future Prospects

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Abstract

We present recent results from the Collider Detector at Fermilab. Searches for the top quark have established a lower bound of $M_{top} > 91$ GeV/c^2 (at 95% confidence level). A measurement of $B^o\overline{B^o}$ mixing has been obtained from $b\bar{b} \rightarrow e\mu, ee$ events. Measurements of b-quark production have been obtained from $e+X$ events and $J/\psi + K$ events. The mass of the W boson has been determined to be $M_W = 79.91 \pm 0.39$ GeV/c^2. In searching for new gauge bosons, we have obtained the bounds $M_{Z'} > 412$ GeV/c^2 and $M_{W'} > 520$ GeV/c^2 (at 95% C.L.). The lower limits on the quark and lepton compositeness scales are 1.4 TeV. In the next two years of data collection, we expect significantly more events for numerous types of physics, due to 25 times more beam luminosity, and improvement to the detector. In the longer term, with "Main Injector" upgrade to the accelerator, further improvements to the detector are being planned to exploit the potentials for physics. We discuss prospects for the discovery of the top quark, precise measurement of properties of b quark, and searches for new physics beyond the Standard Model.

During the 1988–89 CDF data-taking period, the Fermilab Tevatron Collider performed well beyond expectations, providing 200 times the total number of proton-antiproton collisions obtained in 1987. With this larger data sample, CDF has performed extensive searches for the top quark, measurement of properties of the b-quark and of Z and W bosons, and tests of QCD. Since 1989, there have been great efforts in improving the Fermilab accelerators and the CDF detector. In this talk, we present some of the recent results and discuss physics prospects for the next 2 to 10 years.

It has been wonderful in this conference to learn about the abundant and very interesting physics from the e^+e^- colliders. The e^+e^- collisions provide remarkable precision measurements of various parameters, such as M_Z. However, because of the higher center-of-mass energy and larger cross-sections available for hadron colliders, Fermilab is looking forward to the discovery of the top quark, new b mesons and baryons, and other new physics. Hadron colliders and e^+e^- colliders will continue to be both competitive and complementary to each other in the future.

Introduction

The number of events obtained in an experiment can be expressed simply as: $N_{\mathbf{events}} = L\,\sigma\,D$. A large integrated luminosity L is necessary to produce the massive top quark and other rare types of events for new physics with small cross-section σ. The number of protons crossing anti-protons was 4.1 pb^{-1} ($10^{36}/cm^2$) in '88–'89. With improvement in the accelerators, we expect to have 25 pb^{-1} in '92, and 75 pb^{-1} in '93. The typical instantaneous luminosity was 1-2 $\times$ $10^{30}/cm^2/sec$ in '89. With the "Main Injector" upgrade to the accelerator, we expect to have more than $5 \times 10^{31}/cm^2/sec$ starting in 1995, and an integrated luminosity exceeding 1000 pb^{-1} by the year 2000.

The cross-section σ for a physical process depends on the initial and final particles involved. The Fermilab $p\bar{p}$ collider provides the highest center-of-mass energy, $\sqrt{s}$, and the largest cross-sections for many interesting processes such as the heavy quark production [1, 2]. Since the constituents of protons and antiprotons are quarks and gluons, the cross-section for each process in $p\bar{p}$ collisions depends on the parton-parton cross-sections and the parton distribution inside the (anti-)proton. Cross-sections so calculated, such as W, Z, and jet productions, although more complicated than for e^+e^- processes, have been in excellent agreement with experimental data. Cross-sections at $\sqrt{s}$ = 1800 GeV range from $p\bar{p}$ total cross-section of 72 ± 3 mb [3], the production cross-section for a 150 GeV/c^2 top quark of 10 pb (10×10^{-36} cm^2) to even smaller values for other new physics. The predicted cross-section for b-quark production agrees with CDF data to a factor of two, and we expect the predicted cross-section for the much heavier top quark to be accurate to within 30%.

To observe the events produced with sufficient beam luminosity and cross-section for the physical process, the detector must have a good detection efficiency, D. The CDF detector has enabled us to detect and study Standard Model ingredients e, μ, γ, quark jets, gluon jets, ν, τ, $W^\pm$, Z^0, and mundane particles such as $\pi^\pm, \pi^0, K^\pm, K^0$, and Λ^0. The b-quark and c-quark physics results from the '89 data are comparable to data from other experiments, and the CDF detector proved to be an excellent, versatile top detector. The detection efficiency for the top quark increases as we look for top quark in the higher mass region. In addition, upgrades to the detector have included improved data acquisition system, a silicon vertex detector, and higher geometric acceptance. Further detector upgrades, such as kaon identification, are being planned along with the increase in luminosity with the Main Injector to achieve the best physics results in the future.

1 Top quark search

Top quarks are expected to be produced at the Fermilab Collider via the process $p\bar{p} \to t\bar{t} + X$ [1, 2]. In the '88–'89 data sample of 4.1 pb^{-1}, 1200 (30) $t\bar{t}$ events are expected to have been produced in CDF if $M_{top} = 80$ (160) GeV/c^2. In the mass region near $M_{top} \approx 150$ GeV/c^2, a 20 GeV/c^2 heavier top quark would have a lower $t\bar{t}$ production cross-section by about a factor of 2, and may require twice the luminosity to discover.

Each top quark is expected to decay into a W boson and a b quark ($t \to Wb$). Each W subsequently decays into either a charged lepton and a neutrino or two quarks. Thus, the $t\bar{t} \to W^+bW^-\bar{b}$ events have numerous distinctive signatures involving combinations of several energetic leptons or quark jets. With good identification of electrons, muons, jets, and momentum imbalance due to escaping neutrinos, CDF can search for the top quark using most of these signatures. The efficiency of each signature for detecting top quarks varies as a function of t-quark mass, so that as we look for higher mass top quarks, different signatures become more effective.

The branching ratio for both W's from a $t\bar{t}$ pair to decay leptonically is: 2/81 for $e\mu$, 1/81 for ee, and 1/81 for $\mu\mu$. The cleanest signature for the production and decay of a $t\bar{t}$ pair is the presence of two high P_T leptons (e or μ) in the final state.

Decay modes of $t\bar{t}$ pairs in which one of the W bosons decays hadronically and the other leptonically have larger branching ratios (24/81), but in these channels there are serious backgrounds from W bosons produced in association with jets ($p\bar{p} \to W + jets$). These backgrounds are reduced by looking for a b (or $\bar{b}$) quark in the $t\bar{t} \to W^+bW^-\bar{b}$ decay. Decay modes of $t\bar{t}$ pairs in which both W's decay hadronically also have a large branching fraction (36/81), but it is difficult to distinguish them from multijet QCD backgrounds.

Previously, we reported a limit of $M_{top} > 72$ GeV/c^2 (95% C.L.) based on a search for the decay of $t\bar{t}$ pairs into $e\mu$ pairs: $p\bar{p} \to t\bar{t} \to e\mu + X$ [4]. The data sample contains one $e\mu$ event; it has an electron with transverse momentum of 32 GeV/c and an opposite sign muon with transverse momentum of 42 GeV/c with the azimuthal opening angle between the two leptons of 137 degrees. A firm conclusion about the identity of this event is not possible. However, an upper limit on the top quark production rate can be calculated assuming this one candidate event results from $t\bar{t}$ pair production.

To increase the detection efficiency for top quark production, we have extended that analysis to include the channels ee and $\mu\mu$. The search has also been extended to include electrons at smaller polar angles relative to the beam. In addition, we have searched in *lepton + jets* events for a low P_T muon as a tag of a bottom quark in $t\bar{t} \to W^+bW^-\bar{b}$ decays. No additional top quark candidate events have been observed. In the high P_T dilepton analysis, we expect 0.2 ± 0.1 $e\mu$ events from the process $Z^0 \to \tau\tau$, 0.12 ± 0.01 events from WW, 0.3 ± 0.2 events from QCD $b\bar{b}$ production, and 0.6 ± 0.4 events from fake lepton background [5]. Figure 1.1 shows the upper limits on $\sigma_{t\bar{t}}$ as a function of M_{top} together with the QCD calculation to order α_s^3 of the heavy quark production cross-section from Ref. [1, 2]. At the 95% C.L. we find $M_{top} > 85$ GeV/c^2 for the high P_T dilepton analysis. From the combination of the high P_T dilepton analysis with the b tag analysis, we obtain [5] $M_{top} > 95$ GeV/c^2 at 90% C.L., and

$$M_{top} > 91 \text{ GeV}/c^2 \quad \text{at } 95\% \text{ C.L.}$$

In the absence of discovery of the top quark, the experiment measures the upper limit on the production cross-section, which is compared with the theoretical prediction to obtain a limit on the top quark mass. Both the mass and the production cross-section will be measured when the top quark is discovered.

Precise measurements of the W and Z masses, along with other Standard Model tests, imply that the top quark mass is less than about 200 GeV/c^2 [6]. It has been suggested that the top quark may play a fundamental role in the breaking of electroweak symmetries [7].

In the '92 to '93 Run, scheduled to begin in April 1992, we expect to have 6 to 25 times more data. There will also be detector upgrades such as larger muon chamber coverage, and a Silicon Vertex Detector near the collision point, both of which will improve the detector's ability to identify the b-quarks that arise in $t\bar{t}$ events. While the constraints on the top quark mass will be improved with more precise measurement of the W mass, CDF should be able to explore the full range of M_{top} allowed by the Standard Model. We expect in this next Run to find more candidate events to confirm the existence of the top quark. In the longer term, we will obtain high precision measurements of the W mass and the top quark mass which will provide stringent tests of the Standard Model.

2 B physics

In the '89 data, 30,000 $e+X$ events, 3000 $J/\psi+X$ events, and 900 $e\mu$ events have been reconstructed. The events in these samples are predominantly from the decays of b-quarks. The b-quark events with two leptons, in particular, have small backgrounds and are easily reconstructed. With these samples, we have obtained measurements of $B^0\overline{B}^0$ mixing, b-quark and B meson production cross-sections, and searches for $\Lambda_b \to \psi\Lambda$ and $B \to \mu\mu$. These results indicate the tremendous potential for b physics to be explored at Fermilab.

The phenomenon of mixing, in which a neutral meson transforms into its antiparticle via flavor-changing weak interactions, can provide constraints on the elements of the Cabbibo-Kobayashi-Maskawa matrix. Early evidence of $B^0\overline{B}^0$ mixing was observed at the CERN $p\bar{p}$ collider [8] and at e^+e^- colliders [9, 10]. Recent measurements have been made at CERN [11].

Neutral B mesons, $B_d^0(\bar{b}d)$ and $B_s^0(\bar{b}s)$, may be produced in the reaction $p\bar{p} \to b\bar{b} \to B\overline{B} + X$, where B ($\overline{B}$) refers to all $\bar{b}$ (b) flavored hadrons. In the absence of mixing, the direct semi-leptonic decay of a $B\overline{B}$ pair results in a pair of leptons with opposite charges. The B^0 or $\overline{B}^0$ meson may undergo mixing, $B^0 \to \overline{B}^0$ or vice versa, and subsequently decay semi-leptonically, resulting in a like-sign pair. The magnitude of mixing is determined from the relative rate of like-sign di-lepton pairs

$$R = \frac{N(\ell^+\ell^+) + N(\ell^-\ell^-)}{N(\ell^+\ell^-)} \quad ,$$

where ℓ can be an e, μ or τ lepton. The probability of $B^0\overline{B}^0$ mixing can be expressed as

$$\chi = \frac{prob(b \to \overline{B}^0 \to B^0 \to \ell^+)}{prob(b \to \ell^\pm)} \quad ,$$

where the leptons can come from both direct and sequential B decays and the denominator includes all possible hadrons formed with the b quark. We determine χ using our measured value of R and a Monte Carlo calculation of the contribution from other processes.

In a sample of 900 $e\mu$ events, the like-sign to opposite-sign charge ratio R is measured to be 0.556 ± 0.048 (stat) $^{+0.035}_{-0.042}$ (sys). In the absence of mixing, the expected value of R would be 0.23 ± 0.06. The corresponding number for 212 ee

events is 0.573 $\pm$ 0.116 (stat) $\pm$0.047 (sys) with an expected non-mixing value of 0.24 ± 0.07. The observed excess in R leads to a combined determination [12] of

$$\chi = 0.176 \pm 0.031 \text{ (stat+sys)} \pm 0.032 \text{ (model)},$$

where the last uncertainty is due to Monte Carlo modeling. The muon P_T spectra for the data and for Monte Carlo with the determined mixing and background are shown in Figure 2.1, for like-sign and opposite-sign $e\mu$ events separately.

The value of χ determined above is averaged over all B mesons and baryons that may be produced in an event. These include neutral mesons such as B_d^0 and B_s^0 which transform into their own antiparticles via mixing and charged B mesons and baryons which do not undergo mixing. Our results are comparable and consistent with recent measurements of $B^0\overline{B}^0$ mixing by UA1 and LEP experiments [11].

The measurement of b-quark production provides a test of QCD calculations and may allow a determination of gluon distribution. The bottom quarks can be identified through their semileptonic decays into electrons, $b \to e\nu c$. From the rate of production of $p\bar{p} \to e + X$ events, the production cross-sections are determined [13] to be $1150 \pm 45,\ 210 \pm 80, and\ 53 \pm 21$ nb, for b-quarks produced with rapidity $|y| < 1.0$ and $P_T > 15, 23, 32$ GeV/c, respectively. From the observed $p\bar{p} \to e + D^o + X$ events, the b-quark production cross-section has also been determined to be $450 \pm 100(stat.) \pm 130(syst.)$ nb for b-quarks with $P_T > 19$ GeV/c. A sample of fully reconstructed B mesons with the decay $B^\pm \to J/\psi K^\pm \to \mu^+\mu^- K^\pm$ has provided measurement [14] of the B meson and b quark production cross-sections. We obtain $\sigma(B^-) = 3.0 \pm 1.0(stat.) \pm 1.0(syst.)\ \mu$b for B^- mesons with and $P_T > 9.0$ GeV/c, and

$$\sigma(b) = 6.1 \pm 1.9(stat.) \pm 2.1(syst.)\ \mu\text{b} \qquad \text{for } P_T(b) > 11.5 \text{ GeV/c}, |y| < 1.0.$$

The b-quark production cross-sections are shown in Figure 2.2.

In the '92–'93 Run, we expect 10^6 reconstructed $B \to lepton + X$ events, 10^5 events with $B \to J/\psi + X$, and 50,000 events with $b\bar{b} \to e\mu$. CDF should be able to observe B_s ($\to J/\psi + \phi$) and B_c, to search for rare B decays, and to measure B lifetimes. We hope to measure the time dependence of the $B_s\overline{B}_s^o$ mixing. Major upgrades are planned for both the accelerator and CDF after the 1992–1993 Run. Experience in the next two years will be very valuable towards the long term goal of measuring CP violation in $B^o\overline{B^o}$ system.

3 Electro-Weak Measurements

CDF has obtained numerous measurements [15] of the production and decay properties of W and Z bosons of the electro-weak interaction. One example is the determination of the mass of the W boson [16] to be

$$M_W = 79.91 \pm 0.39 \text{ GeV/c}^2.$$

The radiative correction to M_W depends on various parameters, but is most sensitive to M_{top}. In Figure 3.1, M_W as a function of M_{top} is shown for three values of M_{Higgs}. We hope to achieve a precision on M_W measurement of ± 0.1 GeV/c^2 with 100 pb^{-1} by '93, and ± 0.05 GeV/c^2 with 1000 pb^{-1} by the year 2000.

Extensions of the Standard Model, such as grand unified theories and left-right symmetric models, may contain new vector bosons Z' and W'. We have searched for $p\bar{p} \to Z' \to ee$ or $\mu\mu$ events. The measured lepton pair invariant mass distribution, shown in Figure 3.2, is in excellent agreement with the Monte Carlo prediction for Drell-Yan production of dileptons from Z^0 decay and from virtual photon γ^* decay. The 95 % CL limit on $\sigma(Z') \cdot \mathrm{B}_{\ell\ell}$ as a function of Z' mass is shown in Figure 3.3. Also shown is the predicted $\sigma(Z') \cdot \mathrm{B}_{\ell\ell}$ for a Z' with Standard Model couplings. We obtain [18] a lower limit on the Z' mass,

$$M_{Z'} > 412 \text{ GeV/c}^2 \quad \text{(at 95\% CL)}.$$

Similarly, we have searched for $p\bar{p} \to W' \to e\nu$ or $\mu\nu$ events. The measured transverse mass $M_T^{\ell\nu}$ distribution, shown in Figure 3.4, is in excellent agreement with the Monte Carlo prediction for the production and semileptonic decay of the W boson. The 95 % CL limit on $\sigma(W') \cdot \mathrm{B}_{\ell\nu}$ as a function of transverse mass is shown in Figure 3.5. Also shown is $\sigma(W') \cdot \mathrm{B}_{\ell\nu}$ for a W' with Standard Model couplings. We find [19] for a W' with Standard Model couplings,

$$M_{W'} > 520 \text{ GeV/c}^2 \quad \text{(at 95\% CL)}.$$

In the '92–'93 Run, CDF will begin to probe the gauge couplings in the Standard Model from measurement of vector boson pair production. Gauge theories predict dramatic cancellation of diagrams in the production of W^+W^- pairs. The

$W\gamma$ production probes the magnetic moment of the W boson. The $Z\gamma$ production provides a test of Z boson compositeness. Tens of events for each of these vector boson pairs may be expected in the next two years, accumulating to hundreds in a few years.

4 Exotics

With more statistics in the future, we will also continue to search [17] for other new particles: charged Higgs $H^{\pm}$, new vector boson $V \to WW$, and particles in theories with supersymmetry (SUSY). Any discovery of such exotics would lead us beyond the Standard Model.

If lepton and quark are composite particles that have common consituents, an effective (contact) lepton-quark interaction [20]

$$\mathcal{L}_{comp} = \frac{g^2}{2\Lambda^2}(\bar{\ell}\gamma^{\mu}\ell)(\bar{q}\gamma_{\mu}q)$$

would cause a flattening of the dilepton mass distribution at high mass in the process $\bar{q}q \to \ell^+\ell^-$. Based on the absence of electron events with $M > 200$ GeV, we place limits on the scale of such an effective interaction. At 95 % CL, we find [21]

$$\Lambda_{LL}^{-} > 2.2 \text{ TeV}, \qquad \Lambda_{LL}^{+} > 1.7 \text{ TeV}$$

where the scale Λ corresponds to a left-left electron-quark coupling, and the $-(+)$ sign corresponds to constructive (destructive) interference with the dominant u-quark. Similarly for muons, our 95 % CL limits on a muon-quark compositeness scale are

$$\Lambda_{LL}^{-} > 1.6 \text{ TeV}, \qquad \Lambda_{LL}^{+} > 1.4 \text{ TeV}.$$

For the quark-quark interaction, $q\bar{q} \to q\bar{q}$, we obtain [21] the limit on the quark compositeness scale

$$\Lambda_c \quad > \quad 1.4 \text{ TeV } (95 \text{ \% C.L.})$$

from the inclusive jet E_T spectrum (Figure 5.1). The Compton wavelength corresponding to this limit is $< 1.4\times\ 10^{-17}$ cm.

5 QCD tests

For tests of QCD, CDF has studied inclusive jet [21], multi-jet [22, 23], and direct isolated photon productions [24], fragmentation, and α_S. As an example, Figure 5.1 shows the excellent agreement in jet E_T distributions between CDF data and the QCD prediction. The search for quark compositeness will continue and we will also measure quark and gluon distributions inside the proton.

In QCD, at lowest order, prompt photon production is dominated by the Compton process ($gq \to \gamma q$), which is sensitive to the gluon distribution of the proton. Prompt photons are produced in the initial collision, in contrast to photons produced by decays of hadrons. We measure prompt photons in a previously unexplored range of fractional momentum ($.016 < x < .070$).

A prompt photon candidate is an isolated cluster in the central EM calorimeter with no charged track pointing at the cluster. The only significant background sources are the decays of the neutral mesons π^0 and η into photons. We employ two methods for statistically subtracting the neutral meson background from our photon candidates: the *profile method* uses the transverse profile of the electromagnetic shower and the *conversion method* counts electron-positron pairs from photon conversions.

The isolated prompt photon cross-section is shown in Figure 5.2. Here we present the profile method in the low P_T region ($14 < P_T < 40$ GeV/c) and the conversion method in the high P_T region ($28 < P_T < 68$ GeV/c). The two methods agree in the region in which they overlap. The inner error bars are the statistical uncertainty and the outer error bars are the P_T dependent part of the systematic uncertainty combined in quadrature with the statistical uncertainty. The P_T independent component of the systematic uncertainty is shown as the normalization uncertainty separately for each of the two methods.

In Figure 5.2 our measurements are compared to a next to leading order QCD calculation [25] using a single set of parton distributions [26] at a renormalization scale $\mu = P_T$. The QCD prediction changes by less than 30% when the parton distributions are varied among commonly used sets; it decreases (increases) by 12% when the renormalization scale is doubled (halved). The calculation includes the experimental isolation cut. The measured cross-section agrees qualitatively with QCD calculations but has a steeper slope at low P_T. Data acquired at the CERN $\bar{p}p$ collider [27] ($\sqrt{s} = 630$ GeV) show similar behavior. One possible cause of the difference between the data and the QCD calculation is the *bremsstrahlung* process [28, 29], in which a final state quark radiates a photon, prevalent at low P_T.

6 Summary

CDF has performed extensive searches for the top quark, measurement of properties of the b-quark and of Z and W bosons, and tests of QCD. The physics results from the '89 data are already very interesting and provide indications of great physics to be harvested in the future. A lower limit on the top quark mass of 91 GeV/c^2 has been obtained at the 95 % confidence level, assuming Standard Model charged current decays for the top quark. CDF will most likely discover the top quark in about two years of data collection. In the next two years, we expect a lot more events for numerous types of physics, due to 25 times more beam luminosity, and improvement to the detector. In the longer term, with "Main Injector" upgrade to the accelerator and further improvements to the detector, our goals are precise measurement of properties of the top and bottom quarks, and of the other fundamental parameters in the Standard Model, and searches for new physics beyond the Standard Model. Physics at Fermilab should be very exciting for the next 10 years.

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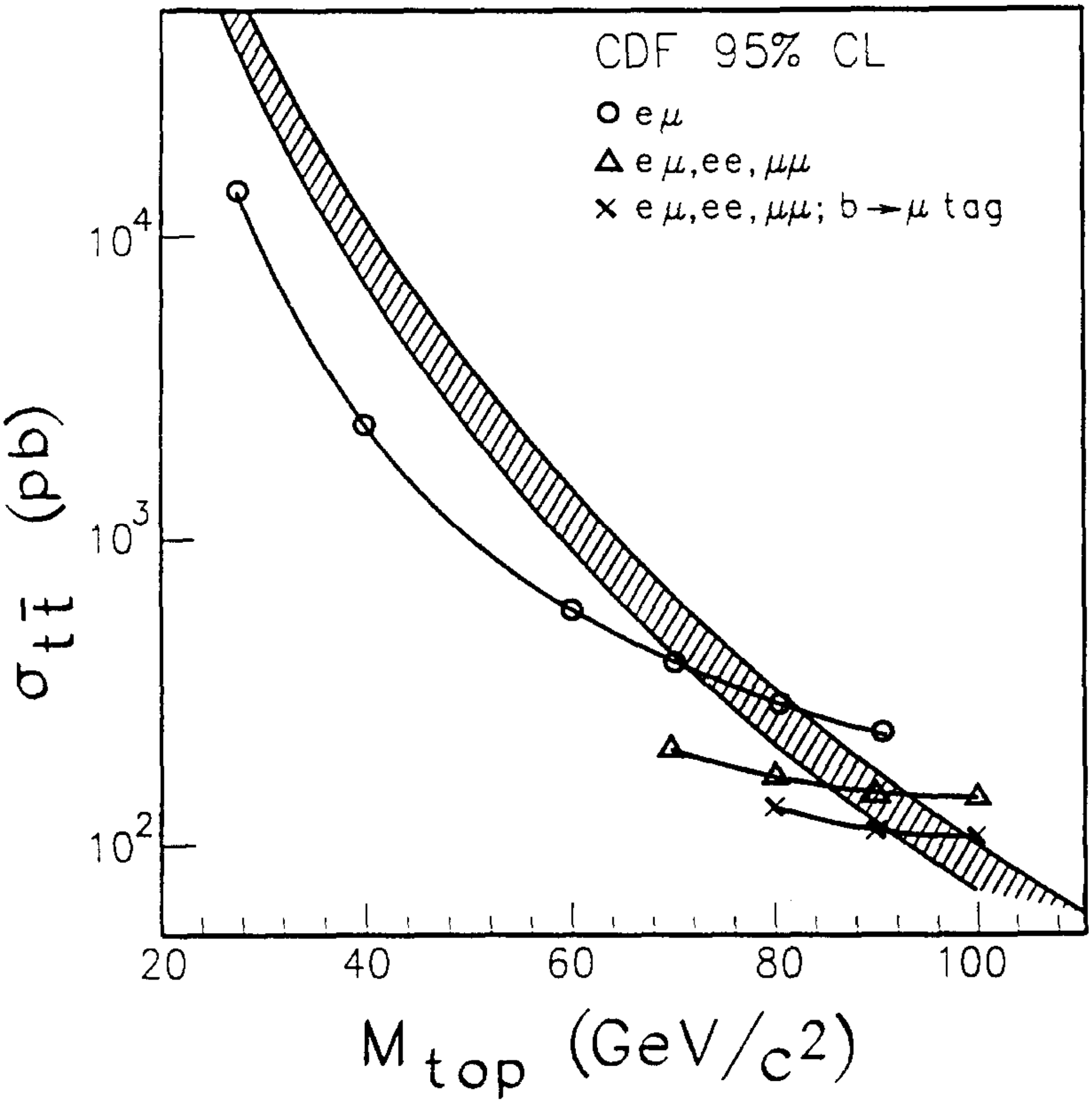

Figure 1.1: The 95% C.L. limits on $\sigma_{t\bar{t}}$ compared with a band of theoretical predictions from Ref. [2]. The three sets of experimental limits are: (1) from the $e\mu$ analysis of Ref. [4]; (2) from this analysis in the dilepton modes ee, $e\mu$ and $\mu\mu$ and including electrons with $1.26 < |\eta| < 2.2$; (3) from the combination of this high P_T dilepton analysis with the b tag analysis.

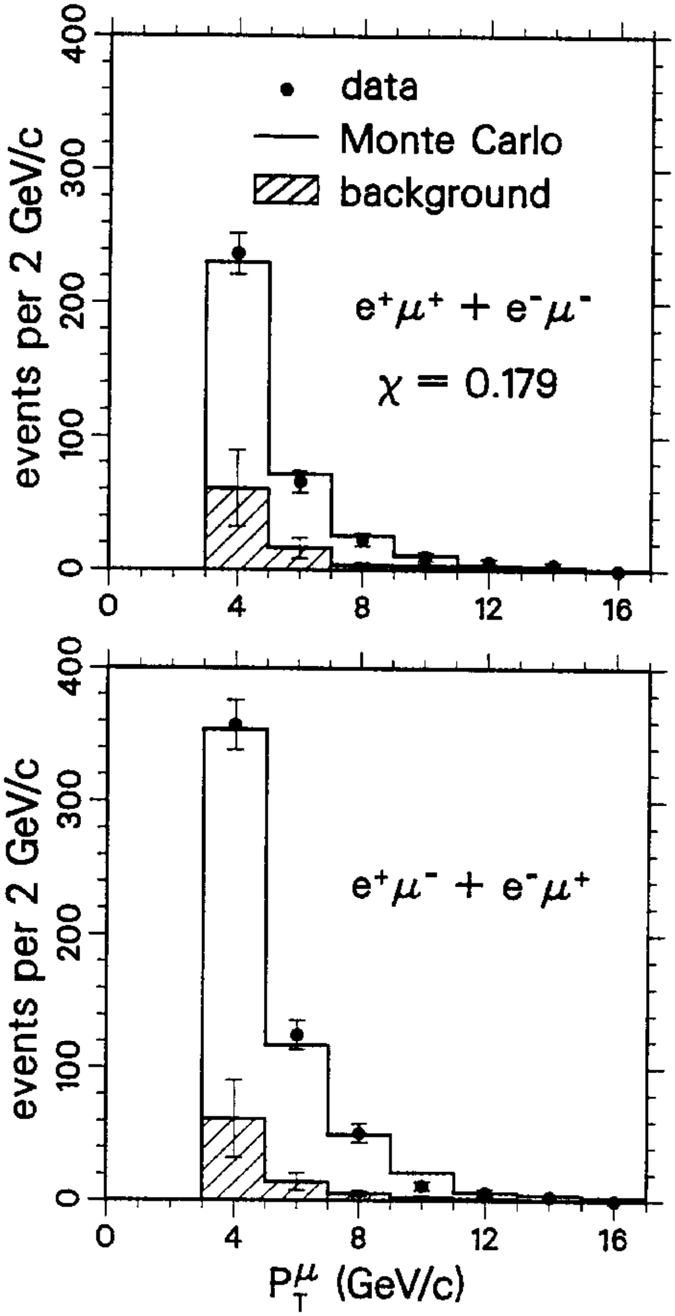

Figure 2.1: Muon P_T spectra for the data, Monte Carlo with the observed mixing, and background in like-sign and opposite-sign $e\mu$ events. Both the data and the Monte Carlo include the background.

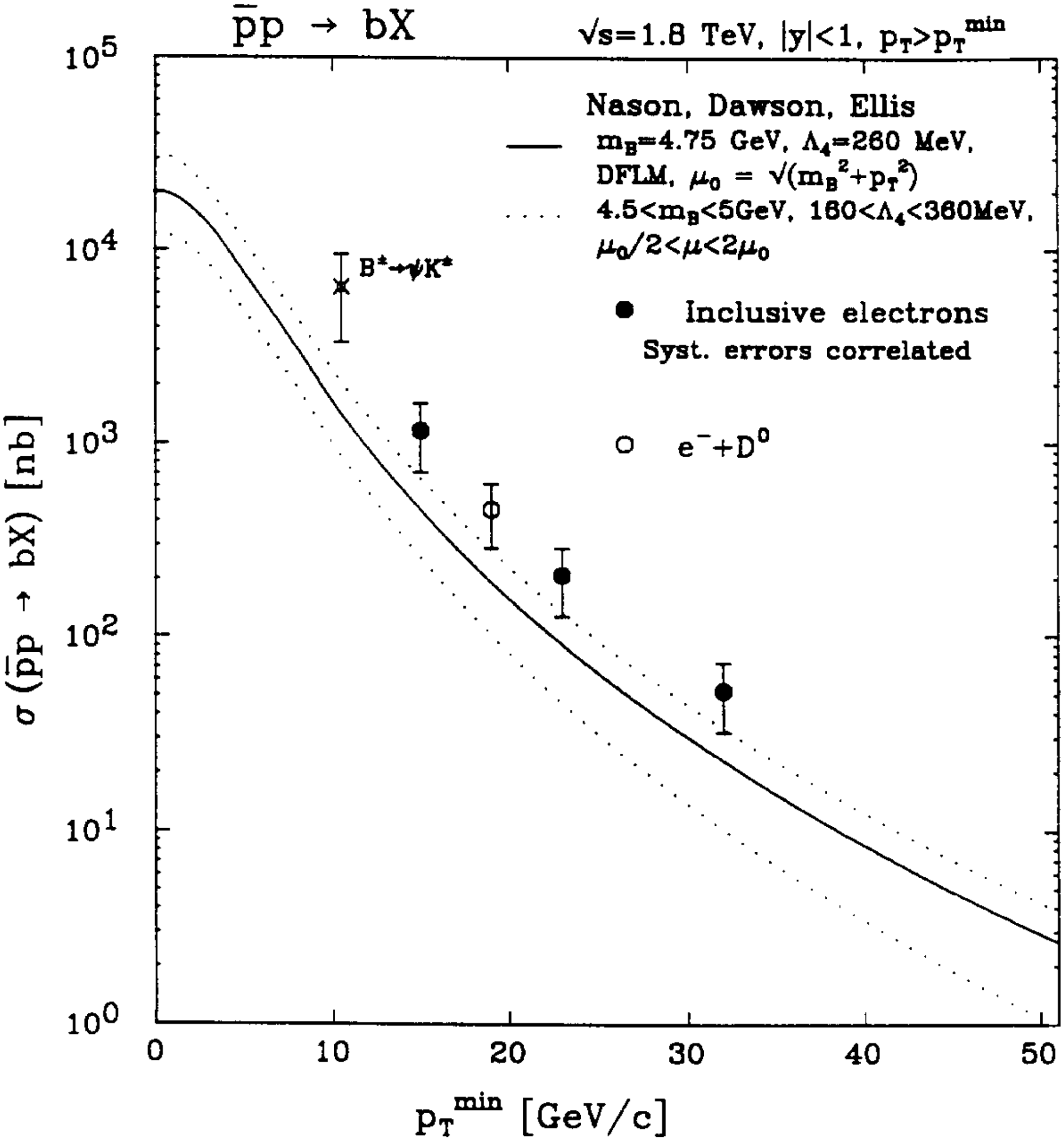

Figure 2.2: The b production cross-section

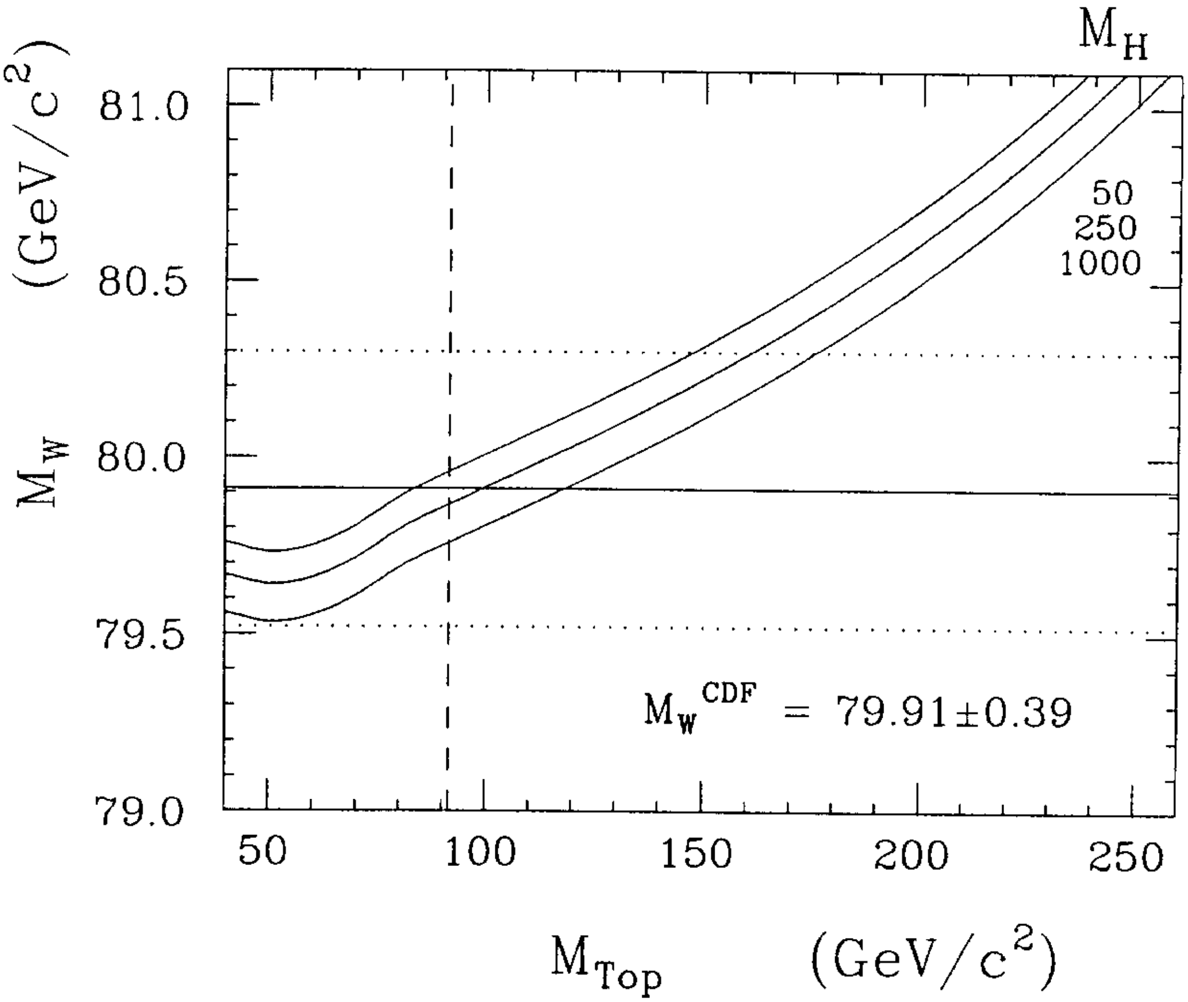

Figure 3.1: W mass vs. M_{top} is shown for three values of M_{Higgs}.

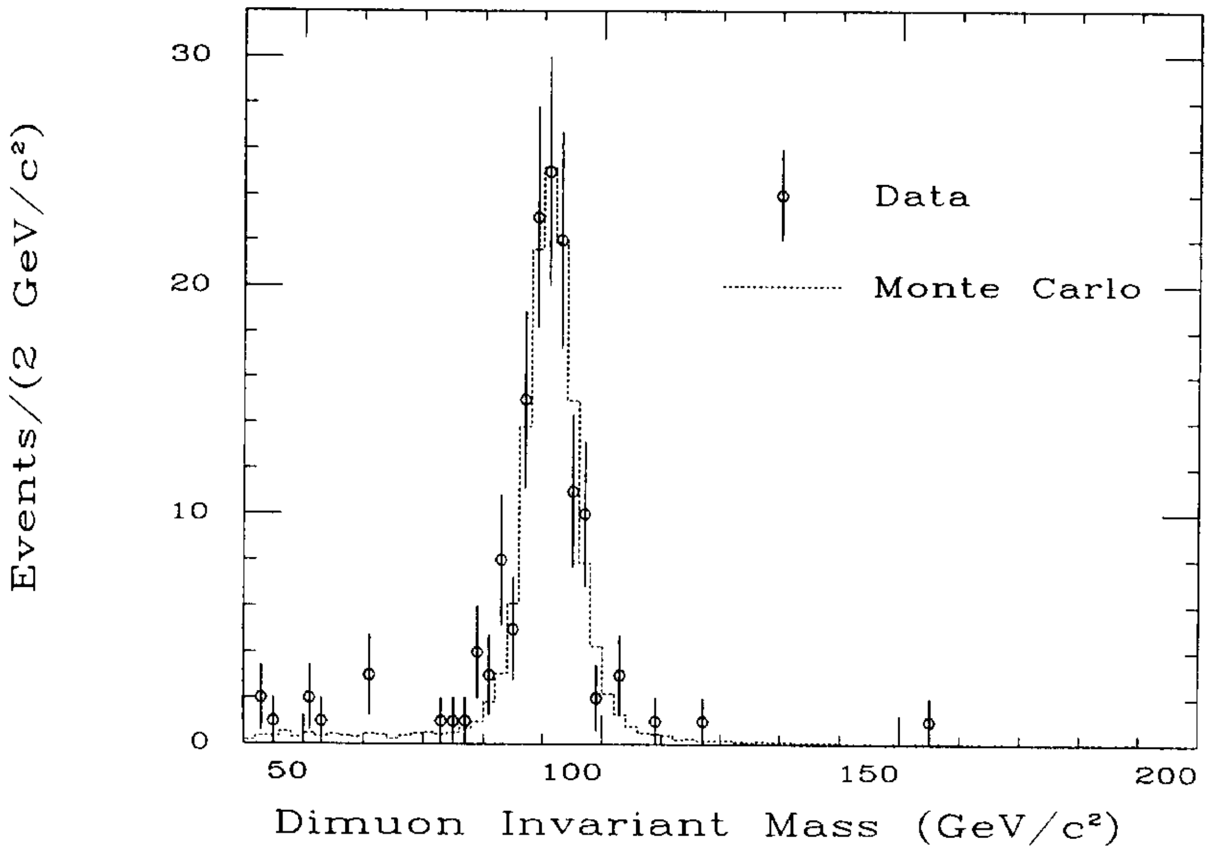

Figure 3.2: The invariant mass distribution for oppositely charged dimuon candidates, compared to Monte Carlo-generated expectations for Standard Model Drell-Yan pairs, normalized to the predicted cross section. There are no events with $\mu\mu$ mass above $M_{\mu^+\mu^-} = 155$ GeV$/c^2$. The observed high mass event is consistent with the SM prediction of 1.05 events for the mass range 130-200 GeV$/c^2$.

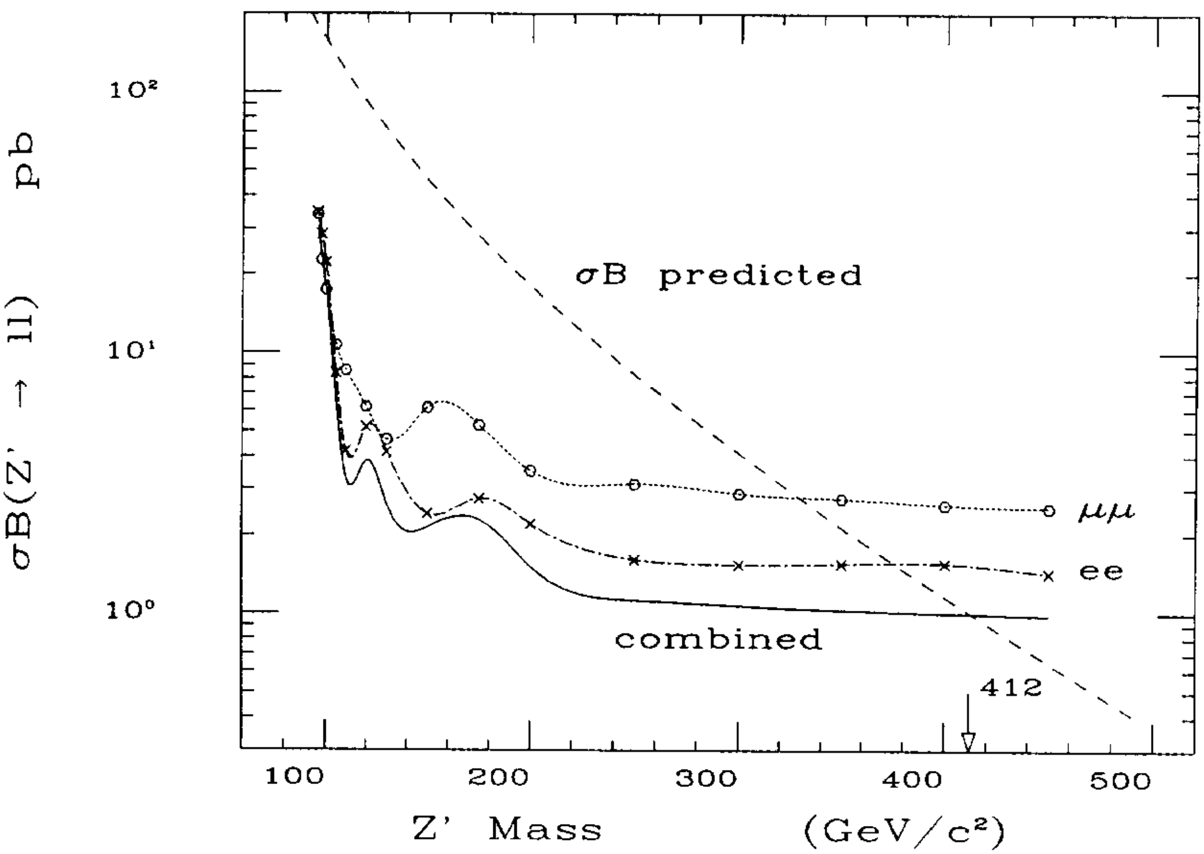

Figure 3.3: The 95% C.L. limit on $\sigma(Z') \cdot B_{\ell\ell}$ for Z' production from the dimuon (dotted line), di-electron (dashed-dotted line), and combined channels (solid line). The points on the lines represent the set of $M_{Z'}$ values at which the fits are performed. The dashed line is the prediction of $\sigma(Z') \cdot B_{\ell\ell}$ assuming SM couplings using the HMRS(B) parton distribution functions. The combined result sets a lower mass limit of 412 GeV/c^2 (95% C.L.), assuming SM couplings.

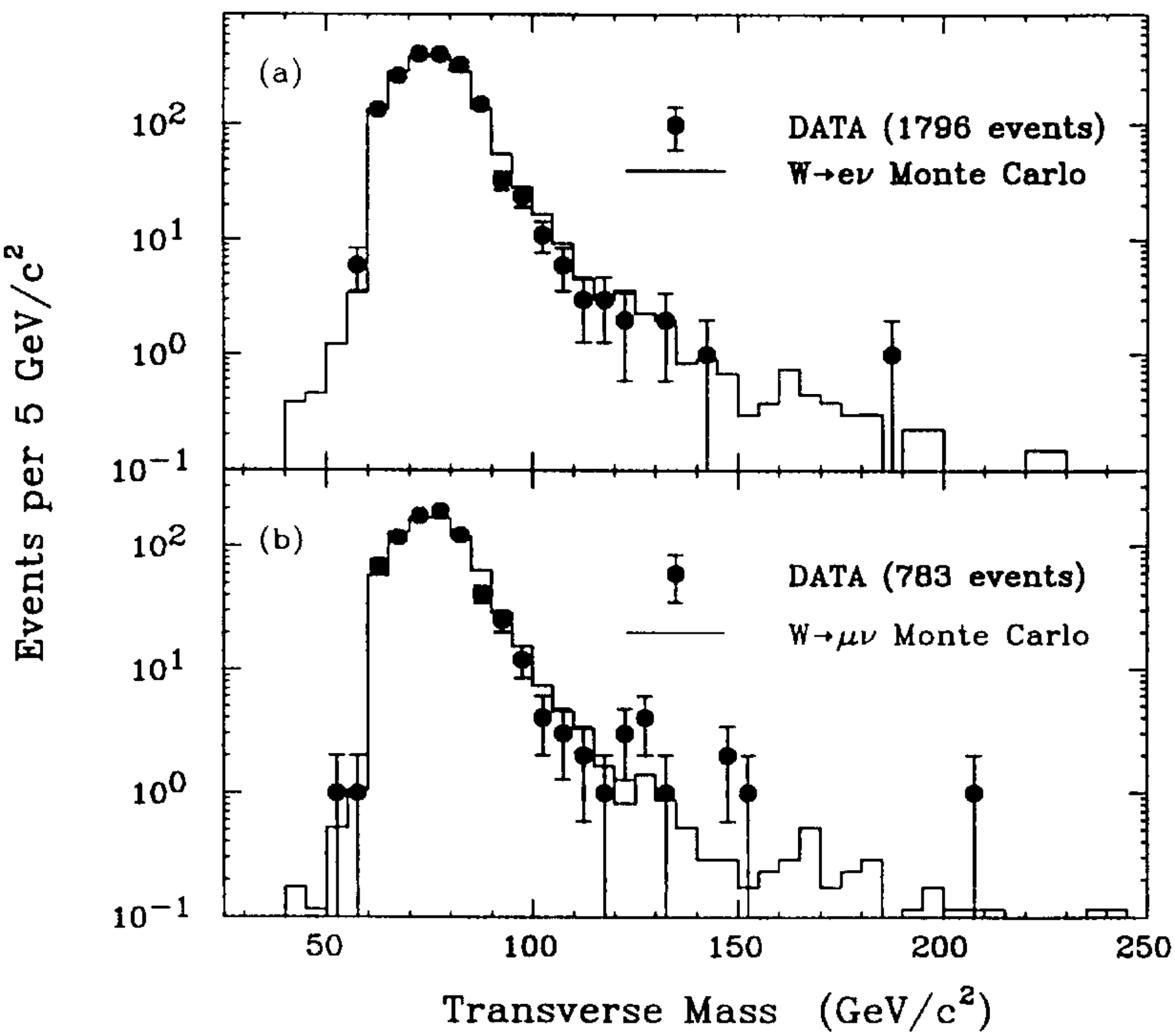

Figure 3.4: The transverse mass distributions for electron and muon samples. Superimposed is the Monte Carlo prediction for W boson decay.

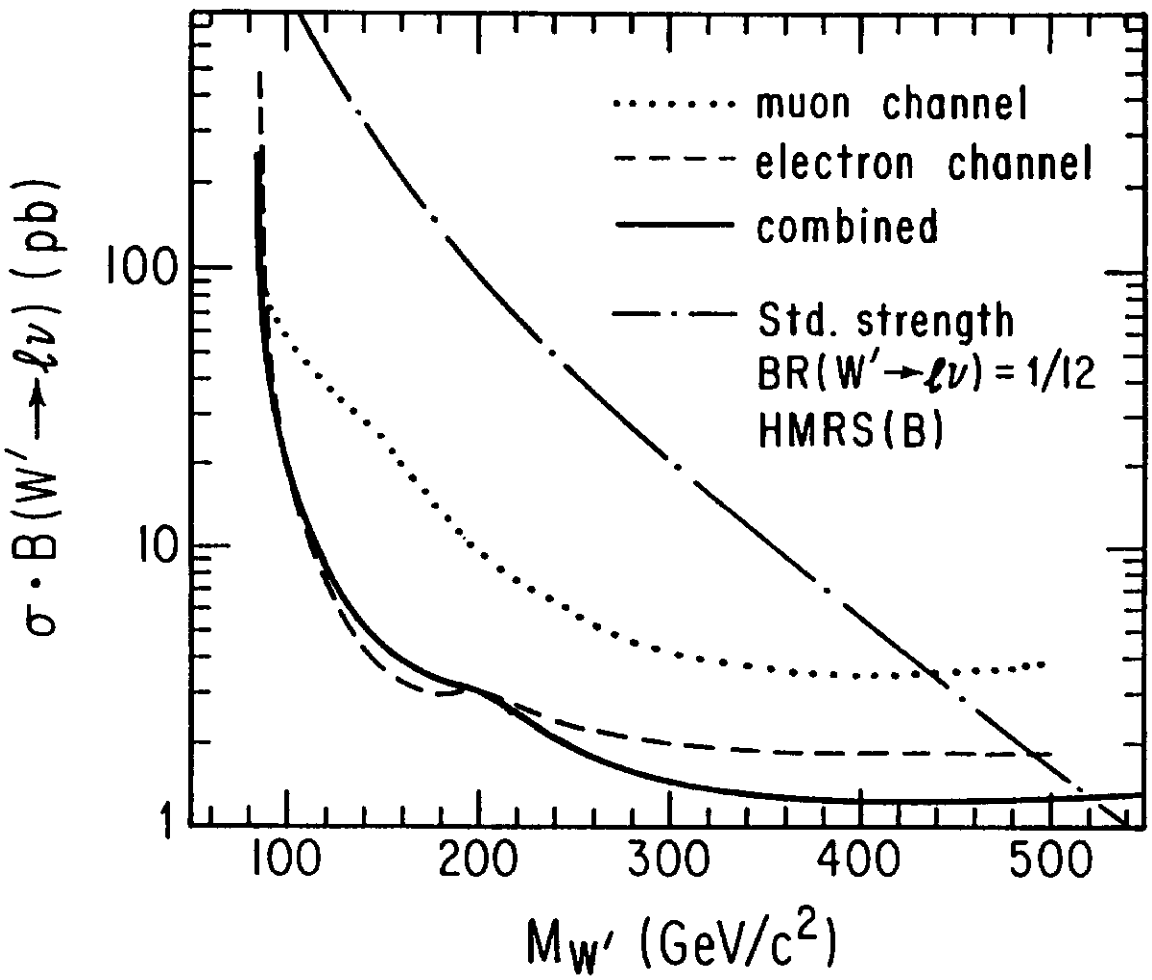

Figure 3.5: The 95% C.L. limits on $\sigma(W') \cdot B_{\ell\nu}$ for $W' \to \mu\nu$ (dots), $W' \to e\nu$ (dashes), and combined (solid). Also shown (dot-dashed) is the predicted value, assuming standard-strength couplings to quarks and a branching ratio of 1/12 to each lepton family.

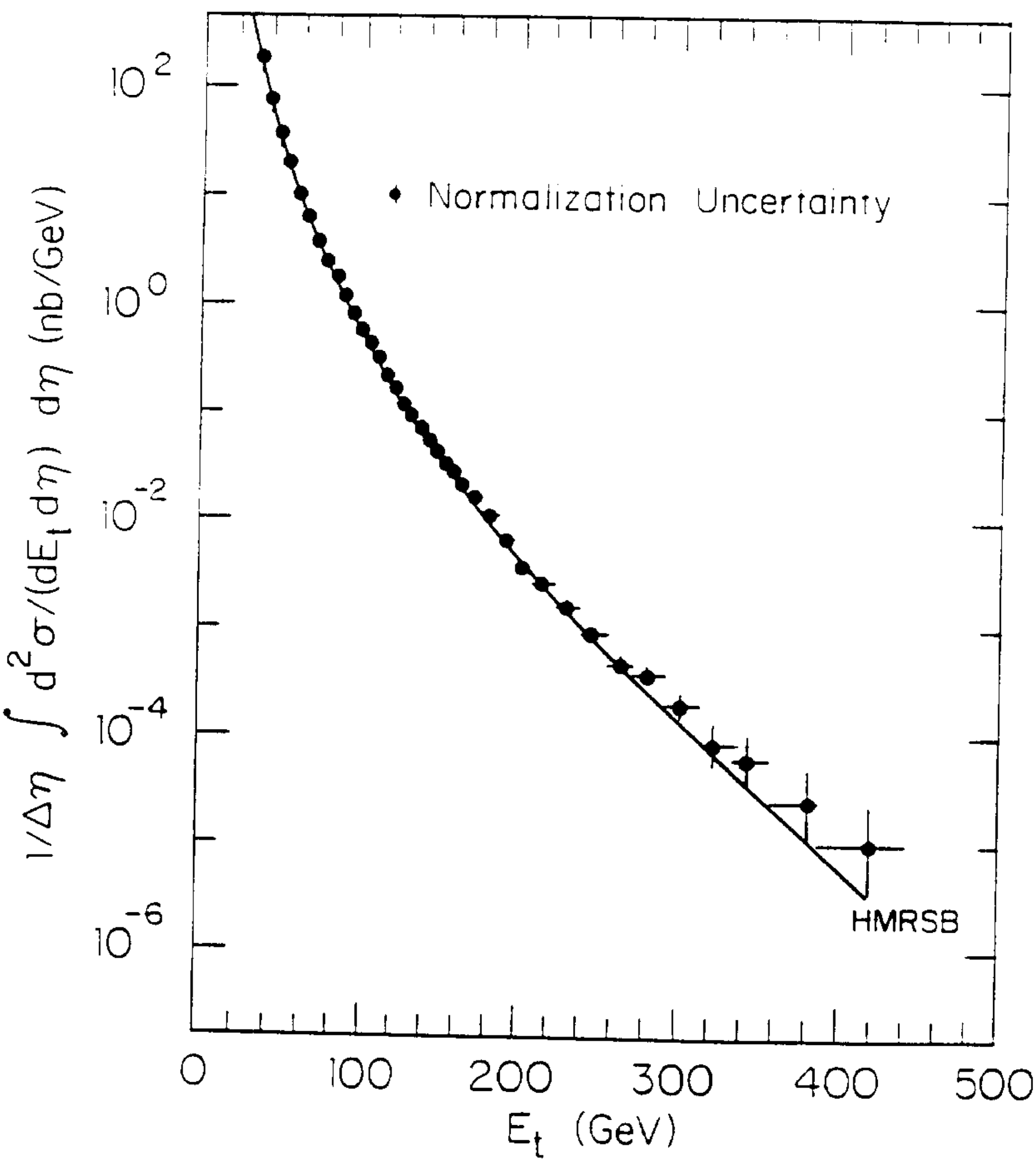

Figure 5.1: The inclusive jet E_T spectrum

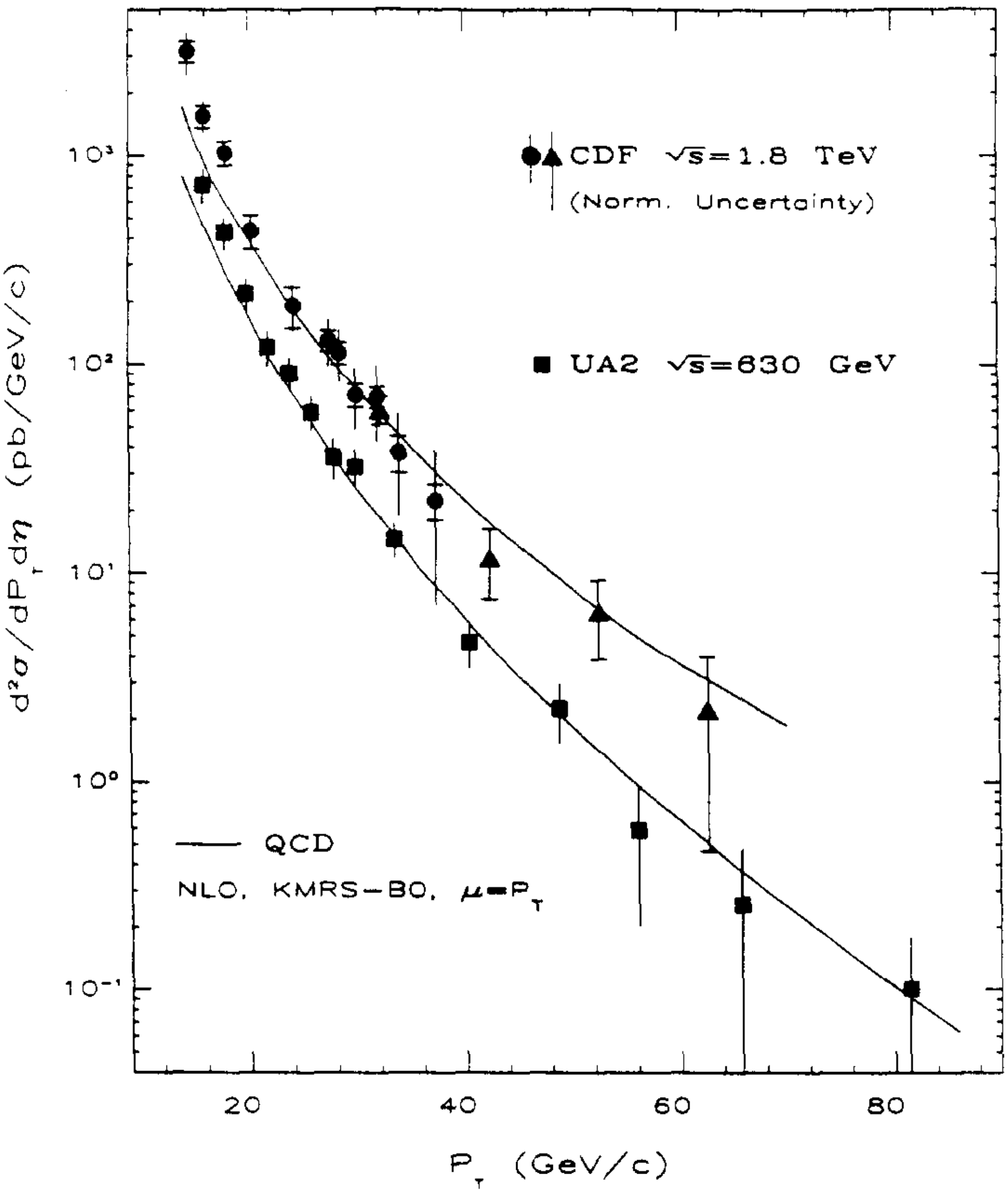

Figure 5.2: The isolated prompt photon cross section, from both CDF (circles and triangles) and UA2 [27] (squares), is compared to recent QCD predictions (curves). The profile method (circles) and conversion method (triangles) have separate normalization uncertainties shown in the legend. The next to leading order (NLO) predictions [25] use current parton distributions (KMRS-B_0 [26]) and a standard renormalization scale ($\mu = P_T$).